

A Four-tier Diagnostic Instrument: An Analysis of Elementary Student Misconceptions in Science Topic

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Abstract: Learning science in elementary schools encourages students to understand the natural environment more deeply, rationally, and scientifically. However, often the scientific concepts they believe about science topics are not in accordance with the scientific concepts they should be. This misconception is difficult for teachers to diagnose. Special instruments to identify and analyze students' misconceptions are needed. Therefore, this research aims to analyze the misconceptions of elementary school students on the topic of energy using a four-tier diagnostic instrument. The purposed-designed survey method was used in this study. The data were analyzed quantitatively and qualitatively. The participants in this study were 20 fourth grade students in an elementary school in Ciamis Regency. A total of 6 questions in the form of a four-tier diagnostic instrument were used to determine the level of students' conceptions. The results showed that the students have misconceptions about the concept of energy. This can be seen from the average percentage of students' misconceptions of 66.67%. This research is expected to contribute to alternative ways to identify and analyze students' misconceptions using the four-tier diagnostic instrument. In addition, it can be used as a reference for teachers and researchers related to the problem of misconceptions of science in elementary school students.

Keywords: elementary students; energy concept; four-tier diagnostic instrument; student misconception.

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Introduction

Science plays an essential role in today's and future global society because science helps humans develop thinking methods and technology both in daily life and in the industry (Shidiq & Yamtinah, 2019; Yuenyong & Yuenyong, 2021). Another benefit is that science education encourages students to understand the natural environment more deeply, rationally, and scientifically (Astuti, Ibrahim, & Hariyono, 2020). However, in the learning process, each student's understanding of a science concept is often different. This difference occurs because each student has a view or conception of the physical world based on everyday

experiences (Fuadi, Sopandi, & Sujana, 2021; Pine, Messer, & John, 2001). The scientific concepts they believe about the world around them are often not following scientific concepts; this is known as a misconception (Alwan, 2011; Karpudewan, Ahmad, & Chandrasegaran, 2017). Misconceptions are individual knowledge obtained from learning experiences or informal events that are not relevant to the scientific concept (Laeli, Gunarhadi, & Muzzazinah, 2020; Soeharto, 2021).

The misconceptions experienced by students will affect their understanding of various natural phenomena. Misconceptions will also have an impact on the process and learning outcomes (Suparno, 2013).

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Students who have a conception following the truth of science will find it easy to build their knowledge. Meanwhile, students who have a misconception of science will have difficulty in learning. This difficulty is very reasonable because in studying science, every concept is related. When a misconception or misunderstanding occurs in one concept, it is feared that the misconception will continue in other science concepts. In addition, previous studies have shown that students' misconceptions tend to be resistant and difficult to convert to scientific concepts (Bayuni, Sopandi, & Sujana, 2018; Hermita et al., 2017). Thus, problems regarding misconceptions must be immediately identified and addressed to achieve scientific concepts and meaningful learning (Baryam, Samsudin, Suhandi, Rusdiana, & Kaniawati, 2017; Cepni, 2009).

Some topics in science learning are abstract and difficult to understand. Energy topic is one of the topics of common misconceptions in the articles reviewed (Laeli et al., 2020; Soeharto, Csapó, Sarimanah, Dewi, & Sabri, 2019). The concept of energy is considered difficult because the material is abstract and mathematical (Millar, 2005). If misconceptions about energy are not immediately identified and corrected at the beginning of students' learning, they will carry these misconceptions to the upper class. This certainly interferes with the quality and quantity of good science learning outcomes for students. Therefore, a teacher needs to identify and analyze the existence of misconceptions in students' minds to prevent further effects on the following science concept.

There are several methods used to identify the emergence of misconceptions in learning. Diagnostic tests are usually used as a tool to identify students' misconceptions (Astuti et al., 2020; Rohmanasari & Ermawati, 2020). Such as Two-tier, Three-tier, Four-tier and Five-tier diagnostic instruments (Bayuni et al., 2018; Moon, Zotos, Finkenstaedt-Quinn, Gere, & Shultz, 2018; Shidiq, Masykuri, & Susanti, 2014, 2015; Yang & Lin, 2015). This type of test has been widely used at various levels of education and subjects such as the two-tier test to identify primary students' understanding of acids and bases (Bayrak, 2013), the three-tier test to identify misconceptions on the topic of human reproduction (Hasyim, Suwono, & Susilo, 2018), and the use of four-tier tests to identify science misconceptions in junior high school students (Caleon & Subramaniam, 2010).

However, the four-tier diagnostic test is a method that is considered more capable of providing a clear description of students' misconceptions. It is supported by the development of four-tier diagnostic tests that have been widely conducted (Yang & Lin, 2015). This test provides a comparison of decisions on

the choice of concepts and the choice of accompanying reasons that can detect a lack of knowledge based on possible student confidence ratings (Gurel, Eryilmaz, & McDermott, 2017). Therefore, this research aims to analyze the misconceptions of elementary school students on the topic of energy using a four-tier diagnostic instrument. This research is expected to contribute to alternative ways to identify and analyze students' misconceptions using the four-tier diagnostic instrument. In addition, it can be used as a reference for teachers and researchers related to the problem of misconceptions of science in elementary school students.

Method

The purpose-designed survey method was used in this study. The research flow design showed in Figure 1. The data were analyzed quantitatively and qualitatively. This method describes in detail the level of understanding of students' concepts based on the results of diagnostic tests. The participants of this study consisted of 20 public elementary school students in Ciamis. All students are from the fourth grade of elementary school. A total of 6 questions in the form of a four-tier diagnostic instrument were used to determine the level of students' conceptions. The research instrument used is adopted from Fuadi et al., 2021. An example of a four-tier diagnostic instrument is presented in Figure 2.

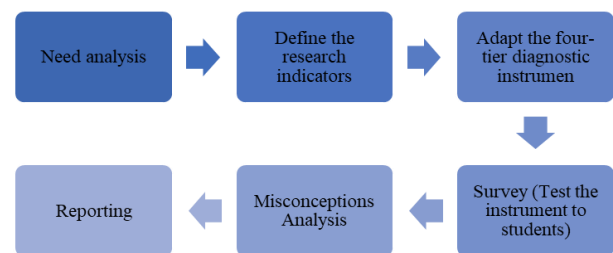


Figure 1. The research flow design

<p>Concept: Batu bara merupakan sumber energi yang dapat dimanfaatkan sebagai pembangkit listrik dan bahan bakar kendaraan.</p> <p>(Tier I) 1. Batu bara diperoleh dari proses... a. Penambangan b. Penimbunan kayu dalam tanah c. Pembakaran batu d. Pembakaran kayu</p> <p>(Tier II) 2. Apakah kamu yakin dengan jawabanmu? a. Yakin b. Tidak yakin</p> <p>Alasan (Tier III) 3. Mengapa kamu memilih jawaban tersebut? a. Batu bara dapat diperoleh dengan mengubur kayu-kayu tua di dalam tanah. b. Batu bara berasal dari batu-batu hitam hasil pembakaran yang lama. c. Batu bara merupakan sejenis arang yang dapat diperoleh melalui proses pembakaran. d. Batu bara berasal dari fosil tumbuhan yang terkubur jutaan tahun.</p> <p>(Tier IV) 4. Apakah kamu yakin dengan jawabanmu? a. Yakin b. Tidak yakin</p>	<p>Concept: Coal is an energy source that can be used to generate electricity and fuel vehicles.</p> <p>(Tier I) 1. Coal is obtained from the process of... a. Mining b. Hoarding wood in the ground c. Stone burning d. Wood burning</p> <p>The first Confidence Rating Scale (Tier II) 2. Are you sure about your answer? a. sure b. Not sure</p> <p>Reasons (Tier III) 3. Why did you choose that answer? a. Coal can be obtained by burying old wood in the ground. b. Coal comes from black stones resulting from long burning. c. Coal is a type of charcoal that can be obtained through the combustion process. d. Coal comes from plant fossils buried millions of years.</p> <p>The Second Rating Scale (Tier IV) 4. Are you sure about your reason answer? a. sure b. Not sure</p>
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Figure 2. Example of a four-tier diagnostic instrument adopted from Fuadi, Sopandi, & Sujana (2021)

The four-tier diagnostic instrument used is in the form of multiple-choice. Investigations conducted through multiple choice with reasons can help in analyzing problems based on certain concepts (Wijayanti, Raharjo, Saputro, & Mulyani, 2018). There are four multiple-choice formats on the diagnostic test used, namely, tier one related to the concept choice; tier two related to the level of student confidence in the answer choices at tier one, tier three related to the

choice of reasons that are in accordance with the concept at tier one, and tier four related to the level of students' confidence in the choice of reasons at tier three. Analysis of students' level of conception is based on the pattern of students' answers. Each student's answer will be determined based on the students' pattern of answers for each level. The results of the combination of student answers can be seen in Table 1.

Table 1. Categories of Student Concepts Based on Answer Patterns

Category	Tier One	Tier two	Tier Three	Tier four
Understand Concept (PK)	True	Confident	True	Confident
Don't Understand Concept (BK)	True	Confident	True	Not confident
	True	Confident	False	Not confident
	True	Not confident	True	Confident
	True	Not confident	True	Not confident
	True	Not confident	False	Not confident
	False	Confident	True	Not confident
	False	Confident	False	Not confident
	False	Not confident	True	Not confident
	False	Not confident	False	Not confident
	Misconception (M)	True	Confident	False
True		Not confident	False	Confident
False		Confident	False	Confident
False		Not confident	False	Confident
Error (E)	False	Confident	True	Confident
	False	Not confident	True	Confident

Source: (Hermita et al., 2017)

Result and Discussion

The level of conception in science learning analyzed in this study is related to energy in the fourth grade of elementary school. The fundamental competencies used are identifying various energy

sources, changing forms of energy, and alternative energy sources (wind, water, solar, geothermal, organic fuels, and nuclear) in everyday life. The results of the analysis of the percentage distribution of students' conception levels consisting of understanding concepts, not understanding concepts, errors and misconceptions can be seen in Figure 3.

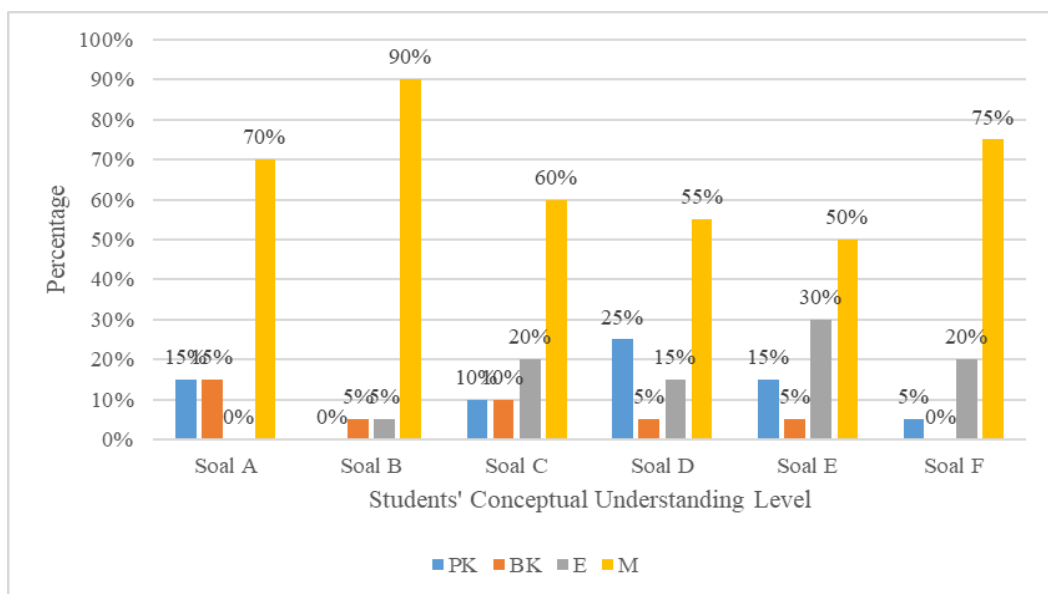


Figure 3. Percentage of Students' Conceptual Level from Each Item

Students do not come to class without empty minds but come with rich knowledge of their physical world based on their daily experiences (Pine et al., 2001). That way, every student has a conception of science before receiving lessons at school (Yamtinah et al., 2019). Analysis of students' concepts with this four-tier diagnostic instrument can be helpful for teachers to identify misconceptions that occur. The results of this identification can be used to improve the learning process so that students have the proper conceptual knowledge (Gomez-Zwiep, 2008). The advantages of the four-tier diagnostic instrument are (1) it can distinguish the level of confidence in the answers and the level of belief in the reasons chosen by students so that they can dig deeper into students' understanding of concepts, (2) can diagnose misconceptions experienced by students, (3) can determine parts of the material that require more emphasis, (4) can plan better learning process to reduce students' misconceptions (Amin, Wiendartun, & Samsudin, 2016).

Figure 3 shows that the level of misconception dominates all students' answers in each item. The highest level of misconception appears in question B about explaining the process to obtain non-renewable energy sources. The misconception is when students understand the wrong concept in terms of labels, definitions, attributes, examples, and values (Astiti et

al., 2020). So it will be very vulnerable to confusion and multiple interpretations if incorrect concepts are associated with other concepts in a piece of information. Students are categorized as having misconceptions when students choose the answer at the first level, and the reason at the third level is wrong, but students choose to believe in the second and fourth levels (Gurel et al., 2017). Although the level of misconception dominates, there are still students who already have scientific conceptions on indicators of alternative energy use, ways to save fuel, sources of electricity, changes and processes for changing forms of energy. Another level that appears with a percentage below 35% is not understanding the concept and errors. The level of not understanding this concept can arise because of the lack of information that students have in drawing the correct conclusion to a concept. Several studies reveal that students do not understand concepts yet can be the basis for misconceptions (Caleon & Subramaniam, 2010; Gurel, Eryilmaz, & McDermott, 2015)

Concepts that are believed by students who experience misconceptions are often referred to as alternative concepts. The alternative concepts that students in each question number most choose are presented in Table 2.

Table 2. Student Alternative Concepts

Code	Indicator	Alternative Concept	Alternative Reason
Question A	Use of alternative energy sources	Wind energy sources can be used as an alternative energy source to replace vehicle fuel.	The energy blows at any time and can be accommodated to move the vehicle.
Question B	The process of obtaining non-renewable energy sources.	Coal is produced from the accumulation of wood in the ground.	Coal comes from black stones resulting from long burning.
Question C	How to save fuel	By riding a private motorbike	Because it is faster to get to the destination and does not spend a lot of fuel.
Question D	Source of electrical energy	The energy source that can be utilized in the waterfall area is wind power	This energy source can be directly flowed into people's homes and converted into electrical energy.
Question E	Energy Changes	The form of energy change in the lamp is electrical energy into light energy only.	When lit, the lamp converts heat energy into energy
Question F	The process of changing the form of energy sources	The tool in hydropower that is used to convert motion energy into electrical energy is the flow of water in rivers.	The rushing water flows directly produces electricity which is then channeled to the windmill.

Based on table 2 the alternative concept of students' choices was wrong, but they believed that the choice was correct. In Figure 3, it is stated that students experience the most misconceptions in question B. This question states to students that "Coal is an energy source that can be used as a power plant and fuel for vehicles. Coal is obtained from the process of...." Then

almost all students who experience misconceptions believe that Coal is produced from the process of stockpiling wood in the ground, not from the mining process.

If students believe that coal is the result of hoarding wood, they will not realize that coal is a non-renewable energy group because it comes from wood.

This is supported by the results of research that proves that elementary school students experience a lot of misunderstandings about energy sources, especially about renewable and non-renewable energy sources (Boylan, 2008; Heron, Stefanel, & Michelini, 2014).

With these findings, gathering information on students' alternative concepts and reasons is very important to know their conceptions. The causes of misconceptions in students can vary, including the condition of students when they receive learning that affects the understanding of concepts that they will receive later, students' experiences in interacting with the environment, the way teachers or educators teach, and selection of learning methods, and books or references (Astiti et al., 2020).

Researchers have conducted studies of learning difficulties and misconceptions on various topics, both at the elementary, middle and college levels, like a misconception on the topic of biology (Fisher & Moody, 2002; Kumandaş, Ateskan, & Lane, 2019), misconceptions of high school students about renewable energy resources and applications (Said Tortop, 2012), and misconception in chemistry topics (Shidiq, Yamtinah, & Masykuri, 2019; Tüysüz, 2009). The methods used by researchers to identify and deal with misconceptions also vary, such as identifying students' misconceptions with the Two-tier multiple-choice instrument (Adodo, 2013; Bayrak, 2013; Chandrasegaran, Treagust, & Mocerino, 2007; Lin, 2004; Othman, Treagust, & Chandrasegaran, 2008; K.-C. D. Tan, Taber, Goh, & Chia, 2005; K. C. D. Tan, Goh, Chia, & Treagust, 2002; Treagust, 2012; Tüysüz, 2009), problem solving instrument (Reigosa & Jiménez-Aleixandre, 2007), and multiple choice instrument (Othman et al., 2008). Meanwhile, addressing the students misconception can be done by changing the concept (Atasoy, Akkus, & Kadayifci, 2009), interview (Kirkwood & Symington, 2009), and modeling (Shin, Espin, Deno, & McConnell, 2009).

The explanation above shows that there have been many ways that researchers have done to identify misconceptions in various topics and levels of education. This research positioned a way to identify misconceptions in students with a four-tier instrument. A four-tier diagnostic instrument is one of the promising ways to identify students' misconceptions. This instrument can be applied to other science concepts, as well as at other levels of education. However, the identification and analysis of students' misconceptions require a follow-up from the teacher. Knowing students' misconceptions is not enough; further action needs to be followed to address students' conceptions. This study recommends further research to address students' conceptions. It is hoped that this

finding can become a reference for teachers to identify misconceptions with the four-tier instrument.

Conclusion

The physical environment provides each student with experiences and shapes their initial conception of nature. Some of these initial conceptions are close to scientific concepts, some of which cause misconceptions in students. Teachers need a way to detect students' initial conceptions to provide the proper treatment to address students' misconceptions. The four-tier diagnostic test is one of the tools used to analyze students' conceptions. Based on the results of the analysis, most students experienced misconceptions on each item about the concept of energy. Students choose the wrong answer related to the concept of energy and believe that their answer is correct. In addition to knowing the level of students' conceptions, the use of four-tier diagnostic tests can also detect alternative concepts chosen by students in answering problems. The results of this study cannot be generalized widely regarding the initial concept of elementary school students about energy because the research participants are still limited. However, this research is expected to contribute theoretically and practically to how to analyze students' conceptual levels and how to describe alternative concepts for elementary school students about energy.

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